preventing rapid elevations and high levels of ICP in head-down tilt postures. These results help the investigators understand how microgravity affects cerebral circulation and fluid balance in an evolutionary context. Furthermore, snakes may provide an excellent model for contrasting the long-term effects of gravity adaptation (arboreal snakes) versus microgravity adaptation (aquatic snakes) on the cardiovascular system.

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Calcium Metabolism in Bion 11 Monkeys

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The calcium endocrine system regulates the supply of calcium and phosphorus for the mineralization of bone, a process that is known to be depressed during spaceflight. The role of circulating hormones in the localized decrease in bone formation in the weight-bearing skeleton is unresolved and difficult to study in the human because of the effects of exercise itself on calcium metabolism. Additional knowledge would not only improve understanding of the mechanism of adaptation to a weightless environment, but also provide a rationale for the use of the hormones of the calcium endocrine system—parathyroid hormone, calcitonin, and the vitamin D hormone (1,25-D)—in the prevention or restoration of bone loss during spaceflight. Currently, therapeutic trials that include these hormones are under way for the human osteoporoses that can result from systemic factors such as estrogen deficiency.

The Bion mission provided the opportunity to examine the effects of spaceflight on the circulating levels of calcium regulating hormones in rhesus monkeys. Bone tissue obtained by iliac-crest biopsy showed clear effects of weightlessness in flight animals, but not in chair-restrained ground controls.

The calcium endocrine study required validation of the human assays used to measure the peptide hormones, parathyroid hormone, and calcitonin because of structural differences in monkey and human hormones. Validation involved the assay of blood samples obtained before and after a 10-minute calcium infusion, and confirmation of the physiologic response. Assays in the laboratory of Dr. Leonard Deftos from the University of California, San Diego, were successful in showing increases in calcitonin, and decreases in parathyroid hormone after calcium infusion, as illustrated in panels A and B of the first figure.

The third hormone of the calcium endocrine system is a sterol that circulates in the rhesus monkey in concentrations seven to ten times higher than in man. To evaluate changes in the levels during spaceflight, serum 1,25-D was monitored during the development of vitamin D deficiency, induced by removing diet sources of vitamin D and exposure to sunlight for four months. The hormone decreased 30, 48, and 83% from basal levels after 1, 2, and 4 months, respectively.

The most striking changes during the 17-day spaceflight were observed in the concentration of vitamin D hormone, which decreased from 75% to 68% in the serum of flight monkeys, and from 27% to 73% (average 54%) in five ground controls, as illustrated in the second figure. At the whole body level, this hormone functions to facilitate calcium transport in the intestine, kidney, and bone, and to differentiate bone cells. Theoretically, a decrease in the level of circulating hormone would not only reduce intestinal calcium and phosphorus absorption, but also indirectly reduce bone resorption. This might be considered an appropriate physiologic response for an unloaded, inactive skeleton, a view that is supported by results from a human bed-rest study in which isokinetic exercise which loaded bone prevented both a decrease in serum 1,25-D, and an increase in urinary calcium excretion. The spaceflight response was not greater than the response on Earth, an indication that the endocrine regulation of

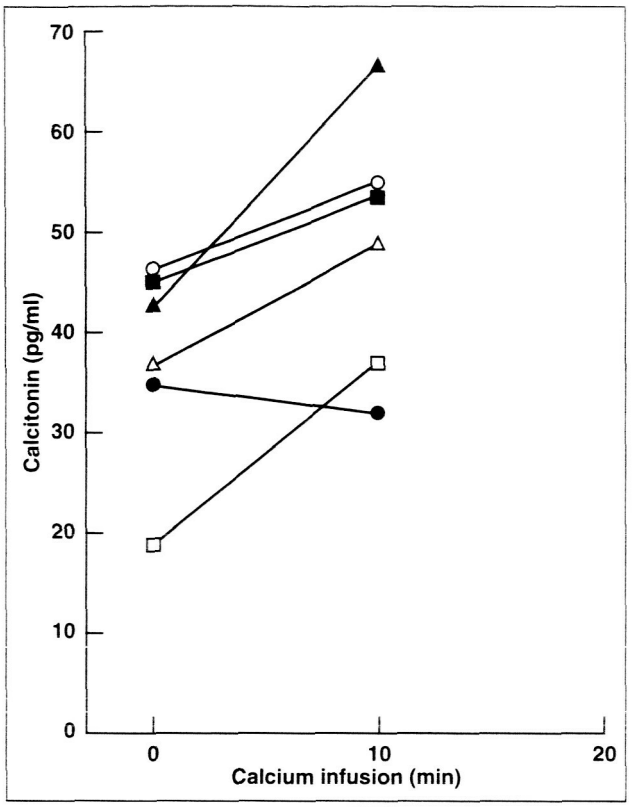

Fig. 1. Panel A: The effect of a 10-minute infusion of calcium on the concentration of serum calcitonin in six monkeys. The infusion increased serum ionized calcium from 1.25 millimoles per liter to 1.44 millimoles per liter.

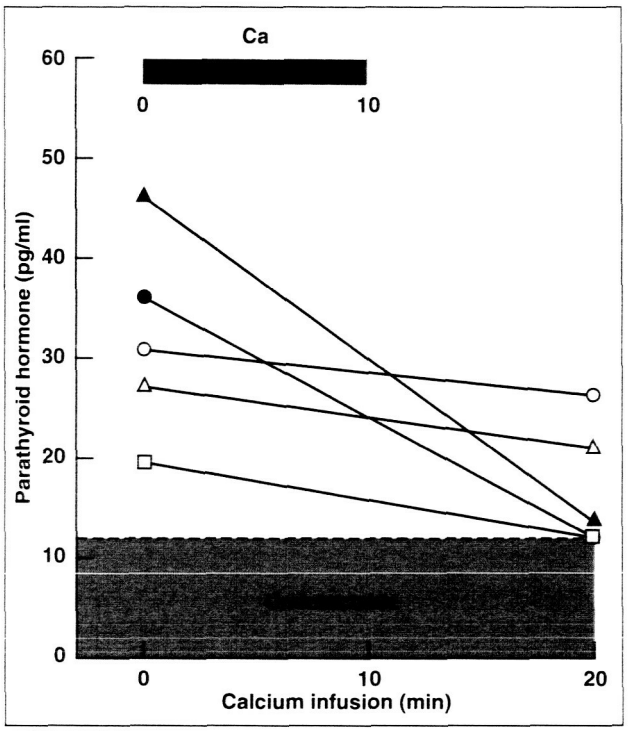

Fig. 1. Panel B: The response in serum parathyroid hormone 10 minutes after the end of the same infusion of calcium in five monkeys as in panel A. In three, circulating levels were depressed to values of 12.1 picograms per milliliter, or the limit of detection of the assay.

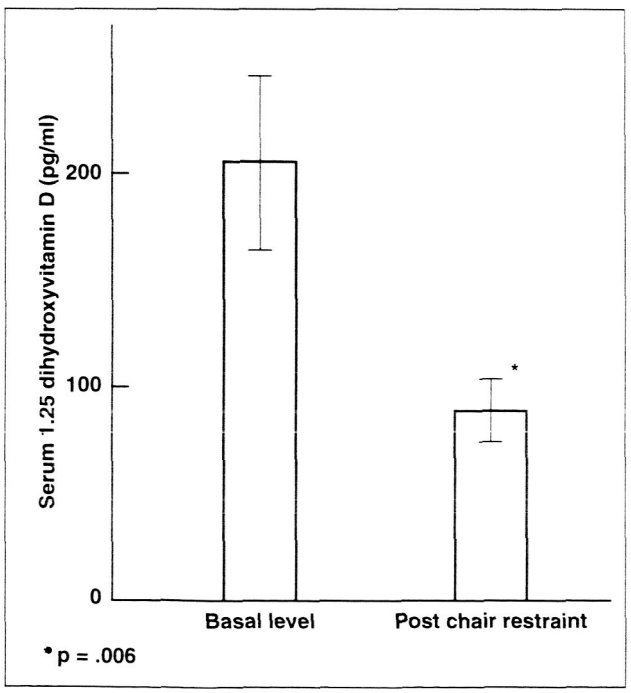

Fig. 2. The effect of chair restraint on the circulating concentration of the vitamin D hormone (1,25-dihydroxyvitamin D).

calcium metabolism at the whole body level in these spaceflight animals was not impaired. The components of the calcium endocrine system associated with the localized findings in bone tissue were not identified.

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